Smartphone and GPS technology for free-roaming dog population surveillance - a methodological study

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Veterinaria Italiana 2015, **51** (3), 165-172. doi: 10.12834/VetIt.233.2163.3
Accepted: 23.11.2014 | Available on line: 30.09.2015

Keywords
Android® application,
Canis familiaris,
Free-roaming dog,
GPS Technology,
Population estimation,
Smartphone.

Summary
Free-roaming dogs (FRD) represent a potential threat to the quality of life in cities from an ecological, social and public health point of view. One of the most urgent concerns is the role of uncontrolled dogs as reservoirs of infectious diseases transmittable to humans and, above all, rabies. An estimate of the FRD population size and characteristics in a given area is the first step for any relevant intervention programme. Direct count methods are still prominent because of their non-invasive approach, information technologies can support such methods facilitating data collection and allowing for a more efficient data handling. This paper presents a new framework for data collection using a topological algorithm implemented as ArcScript in ESRI® ArcGIS software, which allows for a random selection of the sampling areas. It also supplies a mobile phone application for Android® operating system devices which integrates Global Positioning System (GPS) and Google Maps™. The potential of such a framework was tested in 2 Italian regions. Coupling technological and innovative solutions associated with common counting methods facilitate data collection and transcription. It also paves the way to future applications, which could support dog population management systems.

Studio metodologico sull'applicazione di smartphone e tecnologia GPS alla sorveglianza delle popolazioni di cani vaganti

Parole chiave
Applicazione Android®,
Cani vaganti,
Canis familiaris,
Stime di popolazione.

Riassunto
I cani liberi di vagare senza la supervisione di un padrone rappresentano una potenziale minaccia alla qualità della vita nelle città, sia da un punto di vista ecologico, che sociale che di salute pubblica. Uno dei problemi di maggior preoccupazione è il ruolo che i cani randagi hanno come serbatoi di malattie infettive trasmissibili all'uomo, prima fra tutte la rabbia. Ottenere una stima della grandezza e caratterizzazione della popolazione di cani vaganti in una determinata area è il primo passo per qualsiasi programma di intervento funzionale di controllo del fenomeno. Il metodo di conta diretto rimane il più comune tra i soggetti coinvolti nella gestione delle popolazioni canine e nel controllo della rabbia, anche in virtù della non invasività dell'approccio sull'animale. Soluzioni innovative e tecnologiche applicate a questi sistemi di conta possono agevolare grandemente la raccolta dati, permettendo una gestione dei dati più rapida ed efficiente. Questo articolo presenta una nuova soluzione per la raccolta dati basata su algoritmi topologici implementati come ArcScript nel software ESRI® ArcGIS per la selezione random delle aree da campionare, e su di un'applicazione per dispositivi Android® che integra tecnologia GPS con il sistema Google Maps™. Il potenziale di tale sistema è stato testato in due regioni del centro Italia. L'adozione di queste soluzioni tecnologiche e all'avanguardia associate ai comuni protocolli di conta ha vantaggi intrinseci che possono facilitare la raccolta e gestione dei dati. Future applicazioni di questo sistema potranno aiutare in modo significativo le persone coinvolte nella gestione e controllo delle popolazioni canine vaganti.

Introduction

The ecology and control of free-roaming dogs (FRDs) in urban areas have been the subject of many international studies (Beck 1973, Butcher 1999, Slater *et al.* 2008, Dalla Villa *et al.* 2010) and are still a major concern of public-health organisations such as WSPA (World Society for the Protection of Animals), RSPCA (Royal Society for the Prevention of Cruelty to Animals) and the OIE (World Organisation for Animal Health) (Tasker 2007, OIE 2012). Free-roaming dogs represent a potential threat, both ecological and social, to the quality of life in cities (*e.g.* FRDs may bite or attack people and other animals, cause car accidents, create nuisances and pollution), with severe consequences also for the animals' welfare (Totton *et al.* 2011, Vučinić *et al.* 2011). One of the more urgent concerns is the role of uncontrolled dogs as reservoirs of infectious diseases, rabies in particular, transmittable to humans (Childs *et al.* 1998, Matter *et al.* 2000, Flores-Ibarra & Estrella-Valenzuela 2004). An estimate of the FRD population size and characteristics in a given area is the first step for any successful intervention programme. Direct survey methods are recommended by world organisations as WHO (World Health Organization) and WSPA, and described in detailed guidelines (WHO/WSPA 1990; WSPA 2008). Due to their easy-to-understand formulas, these count methods are still popular among people involved in dog population and rabies management (Fei *et al.* 2012).

Field surveys, even when non-invasive for dogs (*e.g.* photographic capture-recapture), require specific equipment to allow for collecting accurate data, such as cameras, GPS tracker/localisers, topographic maps of the area, transecting equipment and tape measures if using transects (Buckland *et al.* 1993, Childs *et al.* 1998) and clipboards with all record forms. Indeed, when surveyors are walking or cycling in the streets to collect data, this equipment can be a nuisance. Moreover, data transcription for analysis, from paper to an electronic database, becomes more time consuming and less reliable as the amount of data increases. Innovative and technological solutions applied to field surveys can facilitate data handling, with immediate storage of observations, and with better documentation for identifying the observed dogs. Mobile technology is widely applied in several research fields all over the world, allowing for a quick and easy data management, and its uses are very promising for veterinary research (Aanensen *et al.* 2009, Robertson *et al.* 2010). Furthermore, considering that today's mobile-cellular penetration rates are estimated around 128% of the population in developed countries and around 89% in developing countries[1], mobile technology can be easily applied worldwide allowing different cost ranges.

The aim of this work was to develop and test a new data collection framework based on a 3-step solution:

1. the use of pre-defined survey boundaries extracted from the national population census metadata;
2. the random selection of a sample of blocks using a topological algorithm implemented in ESRI® ArcGIS software to colour the map;
3. a mobile phone application for Android® operating system devices, which integrates GPS and Google Maps™ to assist data collection.

This newly developed system was tested in 2 Italian regions. In the rest of this article will show the potential of such framework applied to field dog surveys as an aid for future activities and research on dog population management.

Materials and methods

Selection of sampling areas

Counting of FRDs was conducted in Italian urban areas: the first one located in the Abruzzo region, including 3 municipalities (Pescara, Montesilvano, and Spoltore), the second one in the Molise region, including 2 municipalities (Isernia and Longano).

To reduce the study area, a randomised selection of sub-areas was performed and a 2-step procedure was followed. During the first step, the geographical areas of Abruzzo and Molise were divided into smaller sub-areas. Instead of manually drawing the sub-areas, equivalent in size on a cartographic map (World Society for the Protection of Animals 2008), we chose the available population census boundaries used by the Italian National Institute for Statistics[2] (ISTAT) which provide a subdivision of the territory in polygons. The polygons have different areas but a mean human population of around 250 families each[3]. The accuracy of the geographical data is described in ISTAT metadata[4] and a visual inspection confirmed the correspondence between the elements in the data sources and the territory of our interest (*i.e.* we verified that perimeters of the polygons did not fall on houses, but rather along streets or natural barriers).

During the second step, a randomised sub-sampling of these polygons was performed. To guarantee

[1] ICT Facts and figures. International Telecommunication Union, Geneva, Switzerland, Feburary 2013.

[2] http://www.istat.it/it/archivio/44523.

[3] The maps drawn by ISTAT are available in ESRI® shapefile (.shp) format.

[4] http://www.istat.it/it/archivio/104317.

that each polygon had the same probability of being selected and to ensure that their distribution in the macro-area was uniform, a linear algorithm for map colouring based on 5 colours was used (Williams 1985). The algorithm was implemented as an ArcScript in ESRI® ArcGIS software and allowed for map colouring on the basis of 2 main criteria: a) adjacent polygons and those sharing at least 1 vertex had different colour; b) the total number of polygons for each colour had to be equivalent (Figure 1). After map colouring, the software randomly chose 1 colour.

Development and design of FRD localising and counting system

The application has been developed for Android® compatible devices. Android® is the most popular open-source operating system for portable devices, accounting for the 75% of the market share worldwide in early 2013[5], therefore guaranteeing the use of the application on a number of different devices, including the cheapest models. The application was developed using Java programming language through the Android® Software Development Kit provided by Google[6]. This allowed us to maximise the potential of both the portable device (*e.g.* camera and GPS sensor) and the services made available by Google™ (*e.g.* map visualising). The application was also installed with tools for the visualisation of graphic objects, expressed in kml files and conveniently integrated with the maps. In this way the geographical coordinates of the coloured and enumerated polygons, resulting from the map colouring algorithm, could be integrated in Google Maps™ so to highlight the perimeters and areas to survey (Figure 2). The overlap between the geographical coordinates of the klm map and those of Google Maps™ was complete. However, a possible discrepancy between Google Maps™ and real geographical coordinates could be present. This error is commonly accepted, nevertheless possible margins of error were considered while developing the system.

Thanks to the integrated GPS, when opening the application user interface the user position on

[5] IDC Corporate USA 2013.
[6] http://developer.android.com.

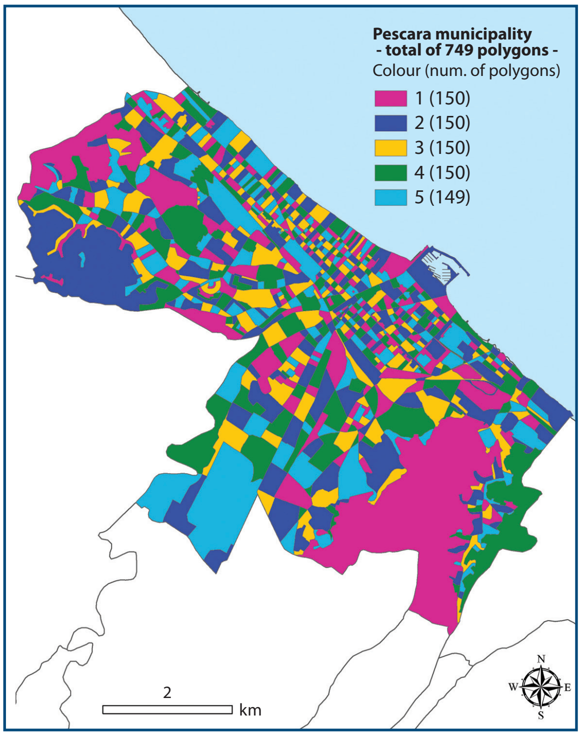

Figure 1. *Example of map colouring: application of the 5 colour algorithm to Pescara municipality (AZ).* The legend shows the number of polygons assigned by the software to each colour.

Figure 2. *Screenshot of the application: the screenshot is showing a portion of Pescara municipality.* Polygons to be surveyed are highlighted and overlapped to Google maps™. Each polygon was identified by a unique progressive number, equivalent to that assigned by ISTAT for the population census. The perimeters of each polygon are also visible when using the street view tool, allowing the surveyor to constantly check while moving if he/she is walking within the sampling area.

Table I. *Information included in the application, recorded through pre-compiled multiple choice menus.*

Data	Menu options	Notes
Sex	☐ Male	
	☐ Female	
	☐ NV (non-verifiable)	
Age class	☐ Puppy (0-6 months)	Estimation based on visual observation
	☐ Young (7-24 months)	
	☐ Adult (3-7 years old)	
	☐ Old (>7 years old)	
Size	☐ Small (<10kg)	
	☐ Medium (11-20kg)	
	☐ Large (>21kg)	
Coat description	☐ Pattern: solid, bicolour, tricolour, parti-colour, brindle, spotted, sable, merle, other.	Selection from multiple choice menus
	☐ Primary colour: black, white/cream, yellow/gold, red/tan, grey/blue, brown/liver, other.	
	☐ Secondary colour: black, white/cream, yellow/gold, red/tan, grey/blue, brown/liver, other.	
	☐ Length: short, medium, long.	
	☐ Coat condition: shiny/clean, dull/dirty, mixed/shedding	
Reproductive status	☐ Pregnant	
	☐ Lactating	
	☐ Female in oestrus	
	☐ Neutered male	
	☐ NA (non-applicable)	
Wears collar	☐ Yes	Estimation based on visual observation
	☐ No	
Shelter nearby	☐ Yes	Presence of a shelter built on purpose for a dog (e.g. wooden shed, quilts or fabric material, bowls available to the animals with water or food)
	☐ No	
Observable health status	☐ No evident health impairments	
	☐ Lameness	
	☐ Excessive thinness	
	☐ Obesity	
	☐ Skin lesions or dermatitis	
	☐ Other (specify)	
Behaviour	☐ Active	Active: exploring, walking, interacting ecc. Inactive: standing, sitting, laying down, sleeping.
	☐ Feeding/foraging	
	☐ Inactive	
Reaction to the surveyor	☐ Approaches (friendly)	
	☐ Approaches (slowly, low posture)	
	☐ Growls/ barks	
	☐ Neutral (*e.g.* ignores the surveyor)	
	☐ Runs away	
Presence of garbage nearby	☐ Yes	Overturned or bursting garbage bins or accumulation of garbage on the road, at a maximum distance of 10m form the dog.
	☐ No	
Location	☐ Garden/ field	
	☐ Bushes	
	☐ Other (specify)	
	☐ Parking lot	
	☐ Underneath a car	
	☐ Road/ sidewalk	
Notes	Free space to write notes	

Veterinaria Italiana 2015, **51** (3), 165-172. doi: 10.12834/VetIt.233.2163.3

Google map was displayed. A drop-down menu on the top of the window lets the user select the name of the municipality surveyed so to overlay the coloured polygons map to the street map. The municipalities listed on the menu were those which klm files had been previously uploaded to the software.

The possibility of changing the view from map to satellite, as in Google Maps™, has also been provided. The drop-down menu has 3 other icons, allowing the user to take a picture or a video of the dog with the portable device camera as well as to open a new 'dog file'. The dog file is a form to be filled with data about the observed dog, while the GPS technology allowed the software to locate the user's position with respect to the selected polygons and recorded, on the dog file, the polygon number and geographical coordinates automatically together with the date and hour. When the GPS cover is momentarily unavailable, the number of the polygon can be inserted manually.

Furthermore, multiple choice menus (Table 1) allow for recording data to identify the target animal (*e.g.* gender, age class, coat), to describe its health status (*e.g.* presence of visible health impairments, reproductive status, cleanliness), to suggest human care (*e.g.* wearing a collar, presence of shelter nearby), to record the environment where it was found (*e.g.* on the road or sidewalk, in a garden, presence of garbage nearby) and its behaviour (active or inactive).

Lastly, users can take pictures or video or select one from the photo gallery, and link it to the dog's file. Data recording is mainly performed with drop-down menus, selecting the input from pre-set definitions, some fields have been left to enter free text. This format allows for a good compromise between the speed and standardisation of the procedure and the possibility of recording all relevant information. The developed application has been installed on a 4.3" display smartphone (Galaxy S2, Samsung Electronics) to get the advantages of good functionality, portability and camera definition. All collected data could be downloaded in an excel format on a computer through USB cable. Alternatively, a compressed (.zip) file containing all collected information could be created and sent via email through the portable device.

Field dog counting

Information on the area and the mean length of the travelable roads within each census boundary, available through ISTAT data, were retrieved to classify the polygons by range of area, leading to a better planning of field activities. A preliminary survey was carried out in order to estimate the mean time needed to walk/drive through polygons of different size. The survey was conducted in Abruzzo (S.AZ) and in Molise (S.MO) between May and June 2012, from 4:30 to 7:00 a.m., before waste removal and before daily human activity and traffic began (*i.e.* around 7:30 a.m.). When the survey was performed, good visibility was possible due to the early sunrise. Two teams of 2 persons each were trained to perform the surveys: 1 person per team (team leader) was the same throughout the study, while the other person (assistant) could vary depending on personnel availability. Observations were carried out either walking along the streets of the selected polygon (urbanised areas and parking lot) or moving by car at minimum speed (peripheral and rural areas). All observations were performed without interacting with the dogs and by maintaining a distance of a few metres from them, in order to avoid fight or feisty reactions.

Results and discussion

This article describes the implementation of innovative technological solutions applied to common dog counting protocols. To sub-sample the survey area, we used the national census boundary maps available on-line in ESRI® shapefile (.shp) format, so that the researcher did not have to hand-draw the perimeters of the sampling blocks. Also, the information on the type of location, polygon areas, and length of streets was immediately available through the national census metadata, which helped when planning the survey activities and timing. Since the maps are created for population census surveys, additional data, such as the number of people per household, the percentage of households with children, the age of residents, are available per each polygon. This information can be useful for socio-demographic analysis linked to FRDs.

Cartographic boundary files are usually available for download through the national statistics government portals[1]. As an alternative for areas where these maps are not available, boundaries can be drawn using GIS tools. In this case, the link to the national census data would not be immediately available. However, the advantages of the application (*e.g.* integrated GPS, camera, standardisation of records, automatic transcription) remain.

[1] Some examples, other than ISTAT, can be found for Ireland (http://census.cso.ie/censusasp/saps/boundaries/census2006_boundaries.htm), UK (http://www.ons.gov.uk/ons/guide-method/census/2011/census-data/2011-census-prospectus/new-developments-for-2011-census-results/2011-census-geography/2011-census-geography-prospectus/index.html), Slovenia (http://www.stat.si/eng/geostatistike.asp), as well as US (http://www.census.gov/geo/reference/outside_sources.html), Canada (http://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2011-eng.cfm) and others.

The random selection of a sample of polygons was automated by implementing a graph algorithm with a map colouring software and then overlapping it to Google Maps™ to mark the areas to be surveyed. For this study, the software extracted 116 randomly distributed polygons to be surveyed. The definition, colouring and selection of the polygons to be surveyed require a certain amount of time to download the ISTAT files and the GIS software from the internet and to implement the algorithms, but overall should not take more than half an hour. Indeed, a manual drawing and colouring of a map would be more time consuming, especially for large areas, since the researcher needs to measure the wards and street length and colour the map so that each adjacent polygon has a different colour. However, it is also true that to use GIS programmes certain expertise is required, so its use by a naïve person would take considerably more time since familiarisation and a learning phase would be needed.

An application for Android® devices was specifically designed to assist the data collection. This solution had the advantage of including several functions and features all in a single portable device (*e.g.* smartphone). The application allowed instant visualisation of the street view or satellite map with all selected polygon boundaries highlighted, to detect the surveyor position through the integrated GPS system and to navigate along the streets within each polygon.

Google maps and all others geographical data contain an inside error due their nature, *i.e.* they bring real tri-dimensional world into a planar surface (geographical projections). Casella and colleagues (Casella *et al.* 2010) calculated the error between the maps provided by Google and the real geographical coordinates in Pavia (Italy). The reported level of accuracy may vary by location, due to the georeferencing process of the specific image (Google maps are a mosaic of images worldwide). In our study, Google maps, used as background map, perfectly overlap the polygons of population census used by the ISTAT.

Once in field, the application, installed on Android compatible devices, displayed 3 superimposed elements: the Google map as background, the perimeter of the areas to survey and the user position. This automatic interaction was possible due to the GPS sensors of the device. Indeed, at some moments the location of the user on the map calculated by GPS sensors may be imprecise, affected by a number of elements However, this error was negligible for the aim of the study because the user constantly compared the polygon borders with the actual area being surveyed thus ensuring that it was noticed when the device indicated a slightly shifted position on the map. Therefore, even when the GPS was out of service, the presence of a dog could always be associated to the correct polygon by manually inserting the polygon number in the dog file. In this case, the geographical coordinates could not be recorded. Nevertheless, since the purpose of a counting method is primarily to count the number of dogs inside each polygon, this aim could always be achieved.

When encountering a dog, a multiple-choice form to record all useful dog data (*e.g.* gener, age, behaviour) could be opened through the application. The user interface with drop-down menus and pre-defined keywords ensured a degree of standardisation of the information retrieved.

Pictures or videos of the dog could be taken with the device camera and matched to the dog file. The potential to remotely retrieve the excel file format of the data collected represents another advantage of this tool, avoiding time losses and errors typical of manual data transcription from field notebook to electronic databases (Aanensen *et al.* 2009). In addition, the possibility to send them through email directly from the portable device, ensures that the information is available for other people involved in the study, who can start a real time data analysis. The application has a very user-friendly interface and, since most people today have Android compatible

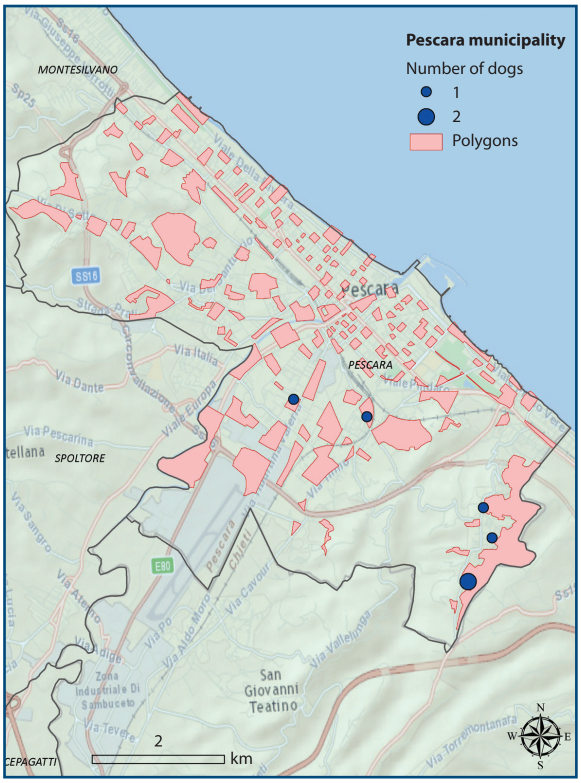

Figure 3. *Example of mapping of dogs localised in the sampled areas: example of distribution and number of dogs counted during the survey in Pescara municipality (S.AZ).*

Table II. *Example of some of the data collected during the surveys and downloaded from the smartphone to the computer in excel format.*

Date	05/06/2012	05/06/2012	05/06/2012	05/06/2012
Hour	05:01:40	05:06:31	05:10:03	05:37:52
Municipality	94023 Isernia	94023 Isernia	94023 Isernia	94023 Isernia
Polygon	222	222	222	228
Latitude	41,519	41,599	41,601	41,615
Longitude	14,127	14,1965	14,1966	14,1928
Observer	S	I	S	S
Size	Medium	Large	Medium	Large
Age class	Adult	Adult	Adult	Adult
Sex	M	M	F	M
Primary colour	Black	White/cream	White/cream	White/cream
Pattern	Bicolour	Sable	Spotted	Solid
Coat length	Short	Short	Medium	Short
Health status	No evident health impairments	No evident health impairments	No evident health impairments	Excessive thinness
Behaviour	Active	Active	Active	Active
Garbage	NO	NO	NO	NO
Location	Road/ sidewalk	Road/ sidewalk	Road/ sidewalk	Road/ sidewalk
Picture	PIC_358488045464810_2012-06-05-050246.jpg	PIC_358488045464810_2012-06-05-050356.jpg; PIC_358488045464810_2012-06-05-050329.jpg	PIC_358488045464810_2012-06-05-050817.jpg	PIC_358488045464810_2012-06-05-053518.jpg

smartphones, there is no specific need for instruction guides or training to use the device.

During this study, 23 dogs were counted in S.AZ and 49 in S.MO. Average time spent to complete each dog file was 30 seconds.

The integrated GPS function of the smartphone reduces the amount of supplies and equipment that need to be carried during a survey, namely the GPS recorder. This feature has an additional twofold advantage. First, once downloaded, the GPS coordinates can be used to map the position of the FRDs observed (as shown in Figure 3); second, the geographical coordinates are automatically linked to the dog file so each dog can be tracked back to its position.

This could also be done with a separate GPS device but the coordinates would have to be recorded by the surveyor on the scoring sheet and then transcribed manually into an electronic format. The application with the dog file can still work off-line and all information can be recorded in the same way, should the GPS or the internet cover fail. It is true however, that if there is no internet in the area, it will momentarily not be possible to visualise the maps of Google.

The multiple-choice menu with pre-defined information to be recorded in the dog file permitted a standardisation of the data collected. Once downloaded, the excel file presented synchronised categories of data, ready to be used for statistical or descriptive analysis on the dog population surveyed. Table II shows an example of data extracted from the application and available as excel format.

The data stored in the software can be sent at any time to an email address. This operation lets the user have immediate access as well as to have a backup of the collected data. This has a great advantage over paper datasheets that can be ruined or lost and that need the extra step and additional cost of data entry before the data can be digitally available for analysis. The application gives no direct advantage on the reliability of the data recorded since the information is still added by the surveyor. However, the pictures and videos associated with the dog file may help to verify that the data were inserted correctly. The portable device, especially the smartphone, is also handy. Instead of carrying the map, the GPS device, the camera, and the scoring sheet, activities can be done using 1 hand and in case of bad weather or to move freely, the device can easily fit in a pocket.

Conclusions

New generation mobile phones and web applications are improving field work in many research areas, due to their built-in GPS, the high quality of web connectivity, integrated cameras, and all this in a handy portable device. Android devices are very popular, hence this new application could also be very cost-saving, as it does not require to buy multiple pieces of equipment, at the same time the surveyors could use their own mobile phones or tablets with no need to buy new ones for the purpose of the study. This application (available upon request) is an example of how technology can help to ease researcher work. However, the fields of application can be wider, helping municipalities, veterinarians and non-governmental organisations involved in dog population management in their census activities, all over the world, including developing nations.

Acknowledgments

The authors would like to thank Adriano di Pasquale for technical support and Ivo Di Bonaventura, Elisa Di Fede, Domenico La Gamba, Antonio Maitino and Valentino Tancredi for their support to field activities. Thanks to Adam Milligan for the English proofreading of this manuscript.

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